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By

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ABSTRACT

Escapement of adult pink salmon to Sashin Creek in 1966 was 5,761 fish--mostly progeny of 1,866 adults transplanted to the stream in 1964. The adults entered Sashin Creek relatively early in the season and within a short period of time. Most of them spawned in the same two study sections of Sashin Creek ("Lower" and "Middle") used by their parents and by earlier native runs of similar size. The two sections had nearly equal densities of females (about 0.27 per square meter) and potential egg deposition (about 570 eggs per square meter) but different efficiencies of egg deposition (about 47 percent in the Middle section and 28 percent in the Lower). The low average efficiency for the entire stream (37 percent) was probably due to the high streamflow during the spawning season. The proportion of combined eggs and alevins alive in March was nearly equal in the Middle and Lower sections (63 and 65 percent), but the disappearance from the end of spawning to just before emergence was markedly different--about 80 percent for the Middle section and 47 percent for the Lower. Total survival from potential egg deposition to preemergent fry was 9 percent in the Middle section and 15 percent in the Lower.

Estimated number of pink salmon fry produced in Sashin Creek in the spring of 1967 was 750,000, or 12 percent of the potential egg deposition of 6,255,000. This is the survival predicted from the historical relation of total fresh-water survival to the date half the spawners entered the stream.

Several lines of circumstantial evidence indicate that the adult pink salmon that spawned in Sashin Creek in 1966 were mostly progeny of the fish transplanted to the stream in 1964.

INTRODUCTION

The pink salmon, Oncorhynchus gorbuscha, invariably has a 2-year life cycle, so that two genetically distinct stocks or lines exist (commonly referred to as the even-year or odd-year line according to the year the fish spawn). In many streams one line consistently comprises far more fish than the other. The relative abundance of the two lines in a stream may persist for many generations, or it may be reversed abruptly in one or two generations. The reason for the greater abundance of one line or the other or the cause of reversal of the relation is usually not known (Ricker, 1962).

To determine the causes for variations in abundance of adult pink salmon the Bureau of Commercial Fisheries has studied this species in Sashin Creek, Baranof Island, Alaska, (fig. 1) since 1934; the abundance of the fish has changed markedly both between and within lines (table 1). From 1934 to 1938 the number of adults returning to Sashin Creek was relatively stable and equal in the two lines. This condition changed abruptly for the progeny of fish that spawned in 1937 and 1938 and has yet to return to the relatively stable and equal condition. The fishing mortality of the Sashin Creek pink salmon is unknown.

After 1944, the annual return of pink salmon of the even-year line to Sashin Creek was fewer than 1,000 fish and gave no indication that this line was going to return to its former abundance. Therefore, an attempt was made in 1964 to reinforce the even-year line with fish from another stream: the Bureau

Figure 1.--Sashin Creek, Baranof Island, southeastern Alaska, site of Bureau of Commercial Fisheries Research Field Station.

Table 1.--Number of adults, potential egg deposition, and fresh-water and marine survival for odd- and even-year lines of pink salmon, Sashin Creek, 1934-66. (Estimates of survival from escapements of less than 1,000 are not given because of the errors inherent in sampling small populations.)

Even-year line					Odd-year line				
Year of escapement	Adults in escapement	Potential egg deposition	Fresh-water survival	Marine survival[1]	Year of escapement	Adults in escapement	Potential egg deposition	Fresh-water survival	Marine survival[1]
	Number	Thousands	Percent	Percent		Number	Thousands	Percent	Percent
1934...	7,917	--	--	--	1935...	6,323	--	--	--
1936...	5,364	--	--	--	1937...	9,085	--	--	--
1938...	6,467	--	--	--	1939...	16,830	--	--	--
1940...	53,594	52,858	6.4	2.71	1941...	84,303	88,678	1.2	1.4
1942...	92,085	78,894	0.8	0.6	1943...	14,883	14,980	1.5	2.4
1944...	4,050	3,904	2.7	0.9	1945...	5,465	5,062	0.8	3.5
1946...	933	736	--	--	1947...	1,486	1,330	2.1	17.5
1948...	597	516	--	--	1949...	4,902	4,800	3.7	2.5
1950...	[2]112	86	--	--	1951...	4,366	4,062	10.1	0.3
1952...	[2]45	--	--	--	1953...	1,164	1,284	7.4	9.7
1954...	21	12	--	--	1955...	9,267	10,286	12.3	1.1
1956...	933	1,018	--	--	1957...	2,834	2,588	21.7	7.0
1958...	217	174	--	--	1959...	35,391	40,379	13.2	0.5
1960...	[2]162	--	--	--	1961...	28,759	29,425	20.2	0.3
1962...	[2]8	8	--	--	1963...	16,757	16,640	19.6	0.5
1964...	[3]2,193	2,230	[4]13.9	1.9	1965...	14,833	12,668	[4]17.9	1.7
1966...	5,761	6,255	[4]11.9	--	1967...	[5]38,067	--	--	--

[1] Marine survival is from fry to adults in the escapement. Fishing mortality is unknown.
[2] An attempt was made to destroy the spawners or their progeny.
[3] Most of these fish were transplanted to Sashin Creek from Bear Harbor.
[4] Fry weir not operated. Estimate based on preemerged alevins in spawning beds.
[5] Personal communication, 1969. W.R. Heard, Fishery Biologist, Bureau of Commercial Fisheries Biological Laboratory, Auke Bay, Alaska 99821.

of Commercial Fisheries and the Alaska Department of Fish and Game in cooperation with the fishing industry transplanted 2,395 adult pink salmon from Bear Harbor, Kuiu Island, Alaska, to Sashin Creek and its estuary (McNeil, Smedley, and Ellis, 1969). The fish were captured on August 24 and were placed above the weir in Sashin Creek between August 25 and 28; they began spawning within 2 days.

I studied the first filial generation of this stock of pink salmon and their progeny in the summer and fall of 1966 and the spring of 1967. The study was designed to continue the long series of data on the abundance of adults and production of fry and to compare the behavioral and biological characteristics of the introduced and native stocks. In this paper I report on the number, sex ratio, length, fecundity, distribution on the spawning grounds, and success of spawning of adults and on survival of their progeny to the fry stage. I compare the fresh-water life history of the transplanted even-year line with recent similar observations of the odd-year line. Information on streamflow and the oxygen content of intragravel water is also given.

There were 2,193 pink salmon spawners in Sashin Creek in 1964--1,139 female and 767 male transplanted fish and 166 female and 121 male fish of unknown origin.[1] The progeny of the 1964 spawning had a fresh-water survival to the fry stage of about 14 percent; about 2 percent of the fry returned as adults in 1966.

Recent History of the Odd-Year Line of Pink Salmon in Sashin Creek

The fish that returned to Sashin Creek in 1939 (progeny of the fish that spawned in 1937) were almost twice as numerous as

[1] Although it is theoretically possible that the 287 fish of unknown origin were progeny of the eight pink salmon that spawned in 1962 (table 1), such a high survival has never occurred at Sashin Creek, and it is more likely that these fish were strays from other streams.

their parents (table 1). The odd-year line continued to increase, and by 1941 the adults were about nine times as abundant as they had been in 1937. But the trend of increasing numbers was reversed for progeny of the escapements of 1941, 1943, and 1945; and the escapement in 1947 was smaller than the escapements before the increase began. For the next five generations (1949-57) the escapement of the odd-year line fluctuated between 1,000 and 9,000 fish.

Then, the progeny of the fish that spawned in 1957 were favored by an unusually good fresh-water survival (21.7 percent) followed by a relatively good marine survival (6.3 percent). The result was an elevenfold increase in the escapement--from 2,800 in 1957 to 35,000 in 1959. From 1959 to 1965 the odd-year escapement fluctuated between 15,000 and 35,000.

Recent History of the Even-Year Line of Pink Salmon in Sashin Creek

The abundance of pink salmon of the even-year line in Sashin Creek parallels that of the odd-year line from 1938 to 1946 (table 1), but since 1948 abundance has been markedly different in the two lines. The number of adults of the even-year line began to increase in 1938, and by 1942 about 92,000 were counted into the creek. As with the odd-year line, abundance of the progeny of this very large escapement declined drastically; the escapements dropped from 92,000 in 1942 to 4,000 in 1944 and only 900 in 1946. Unlike the odd-year line, the even-year line never recovered; it had fewer than 1,000 returning adults from 1946 through 1964. The continued failure of the even-year line was due in part to repeated attempts to kill the few remaining adults or fry in a study of straying (see footnote 2, table 1).

CHARACTERISTICS OF STUDY AREA

Sashin Creek is about 4,000 m. long and originates in a lake at 84 m. elevation. Less than a third of the stream's length can be used by salmon spawners because a waterfall about 1,200 m. from the head of tide prevents further upstream migration. Only a few salmon spawn in the narrow canyon that extends 300 m. downstream from the waterfall or in the intertidal zone because the gradient is steep and the bottom is mostly bedrock. The main spawning ground of Sashin Creek--13,629 $m.^2$--lies between the intertidal zone and the canyon. This study and all other recent work concern a 13,084 $m.^2$ area of Sashin Creek which is divided into three study sections--Upper (2,945 $m.^2$), Middle (4,067 $m.^2$), and Lower (6,072 $m.^2$). These three sections contain 96 percent of the spawning ground available to salmon in Sashin Creek.

Several characteristics of the stream environment bearing on survival of pink salmon and routinely determined in Sashin Creek are bottom composition, oxygen content of the intragravel water, streamflow, and precipitation.

Table 2.--Size composition of bottom materials[1] and average gradient in three study sections of Sashin Creek (McNeil, 1966)

Section	Average gradient	Bottom materials composed of--		
		Cobbles[2]	Pebbles and granules[3]	Sands and silts[4]
	Percent	Percent	Percent	Percent
Upper	0.7	81	16	3
Middle	0.3	61	26	13
Lower	0.1	47	36	17

[1] Materials >15.2 mm. diameter are excluded.
[2] Cobbles are >12.7 mm. diameter.
[3] Pebbles and granules are 1.68 to 12.7 mm. diameter.
[4] Sands and silts are <1.68 mm. diameter.

Bottom Composition of Study Sections

The size composition of the bottom materials varies with stream grade and is assumed to change little from year to year. The Upper section has a relatively steep gradient and coarse materials in the bed; the Middle section has an intermediate gradient and medium-sized materials; and the Lower section has a shallow gradient and fine materials (table 2).

Daily Rainfall and Streamflow

Although extremes in the flow of Sashin Creek are dampened by the water storage of several lakes and bogs in its watershed, prolonged droughts result in low streamflows. Rainfall is usually low at Sashin Creek during July and August and markedly greater in September (fig. 2). Changes in weather followed the average trends in 1966 (fig. 2), and the average streamflows had the same sequence--the average daily flow for each month was lowest in July (0.92 c.m.s.); intermediate in August (1.84 c.m.s.); and highest in September (3.47 c.m.s.).

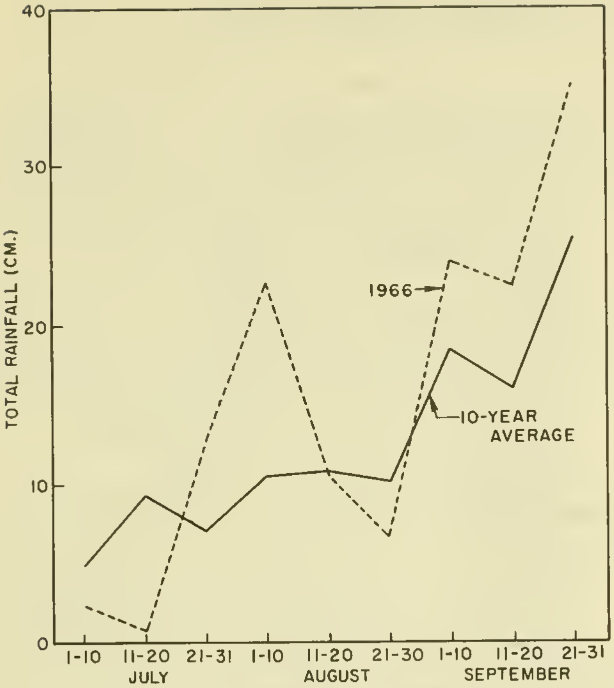

Figure 2.--Total rainfall at Sashin Creek by 10- and 11-day periods in July, August, and September--average for 10 years, 1957-66, and for 1966.

Dissolved Oxygen in Intragravel Water

I determined the concentration of dissolved oxygen in intragravel water of the Sashin Creek spawning grounds on August 21, shortly before the pink salmon began to spawn, and on September 9, near the midpoint of spawning. The dissolved oxygen in intragravel water is replenished by downwelling stream water--the amount of downwelling in general increases as the streamflow increases (Vaux, 1968), and the amount of dissolved oxygen in the intragravel water increases as the streamflow increases (McNeil, 1962). The amount of intragravel oxygen is in general directly proportional to streamflow. The average concentration of oxygen in intragravel water was 6 mg./l. or greater (always more than 50 percent of saturation) in the three sections on both sampling dates (table 3). I believe these values are representative of conditions through the spawning period because they were taken at intermediate flows.

NUMBER, TIME OF MIGRATION, DISTRIBUTION, AND FECUNDITY OF SPAWNERS

The adult pink salmon that returned to Sashin Creek in 1966 were counted and sampled as they passed through a weir at the head of tidewater and again during surveys of the spawning grounds. These fish are assumed to be mostly progeny of the stock transplanted to Sashin Creek in 1964.

The methods and procedures used were those that have become routine for studies of pink salmon in Sashin Creek; most have been described in detail by McNeil (1964, 1966). Males and females were counted daily at

Table 3.--Dissolved oxygen content of intragravel water in Sashin Creek on August 21, before spawning, and September 9, midpoint of spawning, 1966[1]

Study area and date	Water temperature	Samples	Dissolved oxygen concentration: Mean	Dissolved oxygen concentration: 90-percent confidence limits of mean	Degree of saturation
	° C.	Number	Mg./l.	Mg./l.	Percent
Upper					
Aug. 21............	11.4	28	7.6	±0.5	68
Sept. 9............	9.5	29	8.2	±0.5	71
Middle					
Aug. 21............	11.4	30	6.0	±0.6	53
Sept. 9............	9.5	26	8.2	±0.7	71
Lower					
Aug. 21............	11.4	30	6.0	±0.7	53
Sept. 9............	9.5	24	8.4	±0.5	73

[1] Methods of sampling were described by McNeil (1962).

the weir; some females were measured for length; average fecundity was determined; and some females were tagged to determine the distribution of the run on the spawning ground. The number of females in each study section was counted during daily surveys by foot.

Number and Sex of Adults and Time of Migration

A total of 5,761 adult pink salmon were counted at the Sashin Creek weir in 1966 (table 1), of which 3,026 (52.5 percent) were females. The proportion of females in the weir count from 1959 to 1965 had ranged from 48.0 to 56.7 percent.

Pink salmon normally gather in the estuary of Sashin Creek by mid-August and move into the stream in late August and early September as they mature sexually and as freshets occur. The streamflow is rarely so low or high that their migration is blocked. Larger escapements generally enter the stream over a longer period than smaller escapements. In 1966 the escapement of adults entered the stream in a shorter period of time than the average for the last 10 escapements of more than 1,000 fish (table 4). Faster entry was true for both the 10 to 50 percent and 10 to 90 percent segments of the escapement.

Distribution of Females on the Spawning Grounds

The distribution of female pink salmon on the spawning grounds was estimated on the basis of the daily count of all females on the spawning grounds and on the distribution on the spawning grounds of females tagged at the weir. Fifty females were tagged after 27 females had entered the stream; 50 were tagged after 516 had entered, 50 after 1,955, and 29 after 2,940. I assumed that all females counted into the stream (3,026) spawned and that 96 percent (2,905) spawned in the three study sections. These assumptions seem justified because no predation of unspawned females was seen; no dead unspawned females were found; and 96 percent of the spawning ground is within the three study sections.

The distribution of females among the study sections was determined in two ways--(1) from estimates of female-days in each section, based on stream survey counts of all females, and (2) from the distribution of tagged females. In the first method, the number of females spawning in each section was estimated by dividing the total female-days (summed daily counts of females) by the average "redd life" (the average time a female spends on the spawning ground) of the tagged females for each section. The number of females counted at the weir was then apportioned to each section

Table 4.--Dates of stream entry of the 10-, 50-, and 90-percent portions of escapements and elapsed days for pink salmon entering Sashin Creek for the last 10 escapements of more than 1,000 fish, 1947-65, and the introduced even-year line, 1966

Year of escapement	Adults in escapement	Date of entry of portions of the escapement			Elapsed days between dates of entry	
		10 percent	50 percent	90 percent	10 and 50 percent	10 and 90 percent
	Number					
1947........	1,486	Sept. 7	Sept. 14	Sept. 22	7	15
1949........	4,902	Sept. 2	Sept. 12	Sept. 19	10	17
1951........	4,366	Aug. 28	Sept. 6	Sept. 17	9	20
1953........	1,164	Aug. 16	Aug. 29	Sept. 7	13	23
1955........	9,267	Aug. 29	Sept. 1	Sept. 11	3	14
1957........	2,834	Aug. 14	Aug. 22	Aug. 31	8	17
1959........	35,391	Aug. 13	Aug. 29	Sept. 8	16	26
1961........	28,759	Aug. 12	Aug. 14	Sept. 2	2	19
1963........	16,757	Aug. 13	Aug. 27	Sept. 3	14	21
1965........	14,833	Aug. 19	Aug. 26	Sept. 14	7	26
Average....	--	Aug. 18	Aug. 23	Sept. 8	9	20
1966........	5,761	Aug. 26	Aug. 31	Sept. 4	5	9

Table 5.--Distribution of female pink salmon among three sections of Sashin Creek, 1966; 3,026 females were counted through the weir, and 96 percent (2,905) were assumed to be in the study sections

Section	Population estimates of females based on--					
	Female-days and days on redd		Distribution of tagged females		Average of two methods	
	Number	Percent	Number	Percent	Number	Percent
Upper.......	129	4.45	99	3.40	114	3.93
Middle......	1,203	41.41	1,027	35.34	1,115	38.37
Lower.......	1,573	54.14	1,778	61.20	1,676	57.68

Table 6.--Average number of days tagged female pink salmon were on redds in the three study sections of Sashin Creek in 1963, 1965, and 1966

Year	Study section					
	Upper		Middle		Lower	
	Females observed	Average days on redd	Females observed	Average days on redd	Females observed	Average days on redd
	Number	Number	Number	Number	Number	Number
1963.........	13	8.3	36	6.6	37	8.1
1965.........	50	10.9	68	11.7	74	11.9
1966.........	4	14.2	41	17.8	71	20.6

according to its contribution to the total female-day-redd-life estimate for the three sections. In the second method the percentage of tagged females seen in each section was used to prorate the weir count of females to each section.

Estimates of the number of spawning females in each section based on female-days and redd life were similar to those based on the distribution of tagged females (table 5). Since I have no reason to think either method is the better, I used the average of the two for calculating the potential egg deposition in each area. The densities of females on the spawning grounds were about the same in the Lower and Middle sections and markedly lower in the Upper section. The scant use of the Upper section when the total number of females in the escapement is low is usual in Sashin Creek (Merrell, 1962; McNeil, 1968).

Length of Time on Redd

To determine redd life, the presence and location were recorded when a tagged female was first seen on an established redd; on subsequent surveys her presence (or absence) was again recorded. One day was added to the total number of days each female was observed to allow for her presence a half day before the first observation and a half day after the last. The average time of females on redds in Sashin Creek was longer in 1966 than in 1963 and 1965 in each study area (table 6). Several factors may explain the longer average time on redds in 1966: (1) Females entered Sashin Creek and spawned in a few days, so that less energy was expended in prespawning activities; (2) females were large; (3) although streamflows were generally high during spawning, extreme flood conditions did not occur; and (4) because of the small number of females (less than half as many as in 1963 or 1965), antagonism among females on the redd sites was probably less.

Length and Fecundity

Data on length and fecundity of female pink salmon entering Sashin Creek have been collected routinely since 1955 and were collected sporadically in earlier years (Olson and McNeil, 1967). In table 7, I summarize

Table 7.--Average length and fecundity of female pink salmon, Sashin Creek, 1959-66

Year	Females in sample	Average length	Fecundity	
			Average	90-percent confidence limit
	Number	Cm.	Number	Number
1959..........	61	51.5	2,040	±51
1960..........	36	48.6	1,902	±58
1961..........	20	53.0	1,991	±55
1962[1].........	--	--	--	--
1963..........	20	50.8	1,908	±110
1964..........	25	51.4	1,709	±67
1965..........	19	49.2	1,782	±130
1966..........	17	50.5	2,067	±135

[1] No females were measured because total run was only eight fish.

data on length (mideye to fork of tail) and fecundity from 1959 to 1966. The length and fecundity of the stock transplanted in 1964 and of their progeny of 1966 are within the range of values observed in the native stock since 1959.

Efficiency of Egg Deposition

Efficiency of deposition--the success of female pink salmon in burying their eggs in the gravel--is the percentage of the potential egg deposition for the entire escapement estimated to be in the gravel at the end of spawning. This figure can be calculated for Sashin Creek as a whole from data collected with hydraulic sampling gear (McNeil, 1964). The values for each year from 1963 to 1966 are 53, 56, 82, and 37 percent, respectively. The efficiency of deposition was somewhat lower in 1966 than in the previous 3 years; I attributed this lower efficiency to the relatively high, though not flooding, water levels throughout most of the spawning period. Conversely, the high efficiency of deposition in 1965 was attributed to low flow (McNeil, 1968). In the 37-day period August 20 to September 25, the average daily streamflow exceeded 0.7 c.m.s. (about five times the base flow) on only 5 days in 1965, whereas it exceeded this value on 30 days in 1966 (fig. 3).

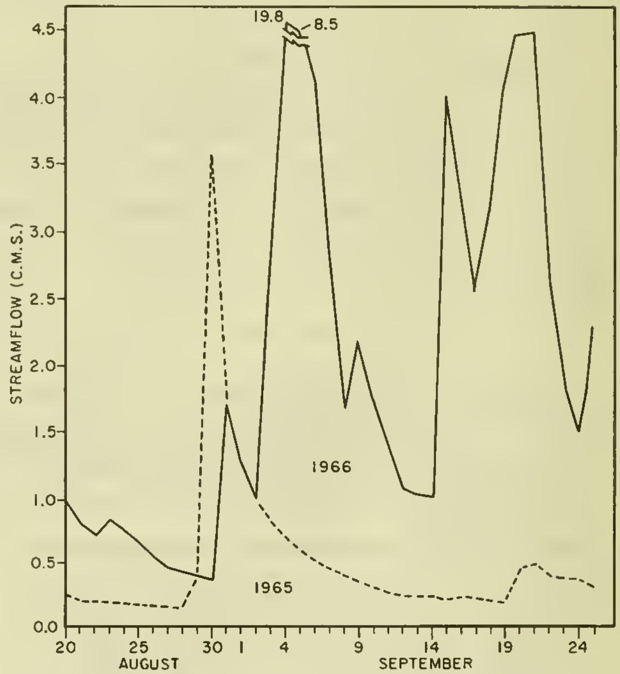

Figure 3.--Daily average streamflow, Sashin Creek, August 20 to September 25, 1965 and 1966. (Data modified from U.S. Geological Survey, 1967.)

Differences in efficiency of egg deposition associated with differences in streamflow may be a major cause of the positive correlation described by McNeil (1968) between early stream entry and high total freshwater survival over the wide range in abundance of spawners in Sashin Creek. The data for Sashin Creek show an inverse relation between rainfall (and streamflow) and earliness of season--i.e., July and August have relatively little rainfall (fig. 2) and low streamflows, whereas September has relatively heavy rainfall and high streamflow. Wickett (1958) demonstrated a positive correlation between the amount of rainfall or stream discharge and survival of a stock (to returning adults) in British Columbia. He concluded that survival of eggs in the gravel appears to be improved by favorable discharge during early incubation.

On the other hand, the correlation between high streamflows during spawning and total fresh-water survival of pink salmon in the Fraser River system was negative (International Pacific Salmon Fisheries Commission, 1968). Low survival in this system was attributed to the death of the eggs spawned on gravel bars at high water and later exposed during low water. In neither British Columbia study was survival determined from potential to actual deposition of the eggs.

Neave (1953) listed three major causes of death of salmon eggs preceding burial: (1) predation on adult unspawned fish, (2) death of adult unspawned fish through other causes, notably as a result of barriers or insufficient water, and (3) loss of eggs through retention in the body or failure of fertilization. I would add a fourth cause: inefficiencies in spawning that cause eggs not to be properly buried and therefore to be lost to predators and scavengers or washed from the stream.

I believe that most of the difference between potential and actual deposition in 1966 was due to the inability of the females to bury their eggs because of high waterflow rather than to removal of the eggs from the gravel by subsequent spawnings. This view is supported by comparing the results of spawning in 1965 and 1966; 82 percent of the potential egg deposition was in the gravel at the end of spawning in 1965, but only 37 percent in 1966. These markedly different "spawning efficiencies" occurred even though (1) the 1965 escapement contained more than twice as many females as the 1966 escapement, (2) the maximum spawning ground counts in 1965 were more than twice those of 1966, and (3) the females remained on the redd for 12 days on the average in 1965 and 19 days in 1966--the greater longevity would give better protection to the redds from subsequent spawners.

SURVIVAL OF EGGS AND ALEVINS

Survival of the progeny of the 1966 escapement was calculated from estimates of the numbers of eggs and alevins in the three study sections of Sashin Creek at three periods: (1) during spawning (early September), (2) after spawning (late September), and (3) shortly before the alevins became fry and emerged from the gravel to migrate to the ocean (early March 1967). The estimate of the number of eggs in each section during spawning (the potential egg deposition) was based on the average fecundity determined at the weir and the estimated number of females that spawned in each section. The numbers of eggs or alevins at the end of spawning and in March (before the fry emerged) were estimated by sampling randomly selected 0.1-m.^{2} areas with hydraulic sampling gear (McNeil, 1964). The number of fry leaving Sashin Creek is usually estimated by trapping at the weir, but this was not done in 1967. Females voided nearly all of their eggs--I examined the body cavities of 38 dead or dying females and found only 423 eggs, or less than 0.5 percent of their potential fecundity.

Estimates of the number and density of eggs or alevins present during spawning and just before emergence of the alevins from the gravel, and estimates of survival are presented for each section and for the entire stream in table 8. So few eggs were deposited in the Upper section (because of few females) that the results of sampling have little meaning. No data are available on the fate of the small number of eggs deposited outside the study sections ("remainder of stream" in table 8). I have therefore used the weighted mean of the fresh-water survival in the Middle and Lower sections to estimate the number of fry produced in the Upper section and the remainder of the stream.

The potential egg deposition for the entire stream in September 1967 was 6,255,000 eggs and the estimated number of live alevins in the stream on March 10, 1968, was 744,000--a total fresh-water survival of 11.9 percent (table 8).

I consider details of the fresh-water survival only for the Middle and Lower sections. Four factors are of special significance: (1) Most (99 percent) of the successfully buried eggs were alive on September 25 (table 9); (2) none of the eggs found in March were alive (all had either died or hatched); (3) most (99 percent) of the alevins found in March were alive; and (4) a much greater portion of the eggs or alevins disappeared from the Middle than from the Lower section from September 25 to March 10 (68 percent versus 20 percent). The similar ratios of live to combined live and dead in the Middle and Lower sections on March 10 (63 and 65 percent--table 9) might be interpreted to mean similar hatching success in the two sections, but such a view may not be justified. A dead egg with an intact chorion is highly resistant to bacterial action[2] and probably to scavenging by invertebrates and may persist in the stream for 18 months (McNeil, Wells, and Brickell, 1964). Dead alevins, however, do not have the protection of a chorion and may decompose rapidly and also be more available to scavengers.

The much greater disappearance of eggs and alevins from the Middle section than from the Lower section (table 9) might be explained in three ways: (1) A greater portion

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[2]Brickell, David C. 1967. Oxygen consumption by dead pink salmon eggs in salmon spawning beds. Manuscript on file Bur. Commer. Fish. Biol. Lab., Auke Bay, Alaska 99821, 107 pp.

Table 8.--Potential egg deposition in August and September 1966, resulting number of live alevins in March 1967, and fresh-water survival of pink salmon in four areas of Sashin Creek

Area	Potential egg deposition		Live alevins		Survival
	Total	Density per square meter	Total	Density per square meter	
	Number	Number	Number	Number	Percent
Upper section....................	236,000	80	[1] 28,000	--	[2] 11.7
Middle section...................	2,305,000	567	199,000	49	8.6
Lower section....................	3,464,000	570	488,000	80	14.0
Remainder of stream..............	250,000	459	[1] 29,000	--	[2] 11.7
Total........................	6,255,000	--	744,000	--	11.9

[1] No live alevins were found in the Upper section in March, and the "remainder" of the stream was not sampled. The number of live alevins here is based on potential egg deposition and an assumed survival of 11.7 percent.

[2] Average (weighted by number of females) of Middle and Lower sections.

Table 9.--Potential egg deposition, number of live and dead eggs or alevins, and calculated survival of 1966 brood year pink salmon in three areas of Sashin Creek. One hundred 0.1-m.[2] samples were taken in each section on each date

Section	Potential egg deposition per square meter		Date	Actual eggs and alevins per square meter						Calculated survival	
				Combined live and dead		Ratio of live to combined live and dead		Live			
	Mean	90-percent confidence limits of mean		Mean	90-percent confidence limits of mean	Mean	90-percent confidence limits of mean	Mean	90-percent confidence limits of mean	Sept. 25 to Mar. 10	Total fresh-water
	Number	Number		Number	Number	Percent	Percent	Number	Number	Percent	Percent
Upper....	80	±5	Sept. 25	116	±109	98	±5	114	±108	--	142.5
			Mar. 10	4	±3	0	--	0	0	--	0.0
Middle...	567	±37	Sept. 25	246	±114	99	±4	243	±105	--	42.9
			Mar. 10	78	±35	63	±28	49	±75	20.2	8.6
Lower....	570	±37	Sept. 25	152	±94	99	±1	149	±61	--	26.5
			Mar. 10	122	±61	65	±29	80	±45	53.3	14.0

of the eggs hatched, and the alevins had a higher mortality in the Middle section; (2) the portion of eggs hatching was the same in the two sections, but the eggs and alevins were removed from the gravel (by scouring or predators) at a higher rate in the Middle than in the Lower section, possibly because of differences in the size of the substrate (table 2); or (3) the difference in calculated survival is due to sampling error.

The results of the sampling in September and March were compared for the Middle and Lower sections by the chi-square test to determine if the changes in portion of samples

Table 10.--Chi-square test of significance of difference between proportion of samples with live and dead pink salmon eggs and alevins in Middle and Lower sections of Sashin Creek, September 1966 and March 1967

Section and date of sampling	Samples	Samples with three or less--		
		Live plus dead	Live	Dead
	Number	Number	Number	Number
Middle				
September 25, 1966	100	72	73	99
March 10, 1967	100	77	86	90
χ^2	--	0.66	5.19	7.79
Lower				
September 25, 1966	100	82	83	100
March 10, 1967	100	81	87	91
χ^2	--	0.63	0.03	11.29

$$\chi^2 = \frac{\Sigma k_o p_o - \bar{p}_o \Sigma k_o}{\bar{p}_o(1-\bar{p}_o)};$$ k_o = number of samples with three or less pink salmon, p_o = proportion of samples with three or less pink salmon, $\bar{p}_o$ = mean of p_o values.

with live plus dead, live only, and dead only were significant. I used the method and notation of McNeil (1964) and also used his designation of categories, i.e., samples with "three or less" and "more than three" pink salmon eggs or alevins. I tested combinations of three or less combined live and dead, three or less live, and three or less dead (table 10). The test showed (1) a significant increase in the proportion of samples with three or less live eggs or alevins in the Middle section; (2) a significant decrease in the proportion of samples with three or less dead eggs or alevins in the Middle section; (3) a significant decrease in the proportion of samples with three or less dead eggs or alevins in the Lower section; and (4) no significant change in the proportion of samples with three or less combined live and dead eggs or alevins in either section.

I conclude that mortality of pink salmon eggs or alevins was greater in the Middle than in the Lower section but can offer no reason for the difference.

The population of the 1966 brood year from number of eggs to number of preemergent fry for each area and the entire stream is shown in table 9. I used the average survival (weighted by surface area) of the Middle and Lower sections to calculate the number of live pink salmon alevins in the Upper section and the remainder of the stream. Although the fry weir was not operated in the spring of 1967, the number of fry counted through the weir had been very close to the number of preemergent fry or alevins estimated in the gravel by hydraulic sampling (McNeil, 1968). I therefore assumed that the production of pink salmon fry in Sashin Creek in the spring of 1967 was the stream population of alevins in March--755,000. This figure represents 11.9 percent of the 6,255,000 eggs carried into the stream by females in August and September 1966.

I calculated the regression of total fresh-water survival against the date on which 50 percent of the escapement had entered Sashin Creek for escapements of 1,000 or more for 17 years from 1940 through 1965. McNeil (1968) presented a similar regression, but he included data from smaller escapements. My empirical estimate of total fresh-water survival for the 1966 brood year is the same as the value calculated from the date of entry of 50 percent of the escapement (the calculated survival for August 31 is 11.9 percent--fig. 4). Thus, the total fresh-water survival of the transplanted stock in 1966-67 was the same as that expected for an escapement of the native stock with the same midentry date.

IDENTITY OF THE 1966 ESCAPEMENT

An underlying assumption of this paper is that the adult pink salmon that entered Sashin Creek in 1966 were mainly progeny of the adults transplanted to Sashin Creek from Bear Harbor in 1964. It is not possible to state positively that this assumption is true, but three types of circumstantial evidence support it. This evidence centers on (1) the amount of straying observed in earlier years, (2) the fresh-water survival of progeny of strays, and (3) the similarities between the transplanted adults and the adults of the 1966 escapement.

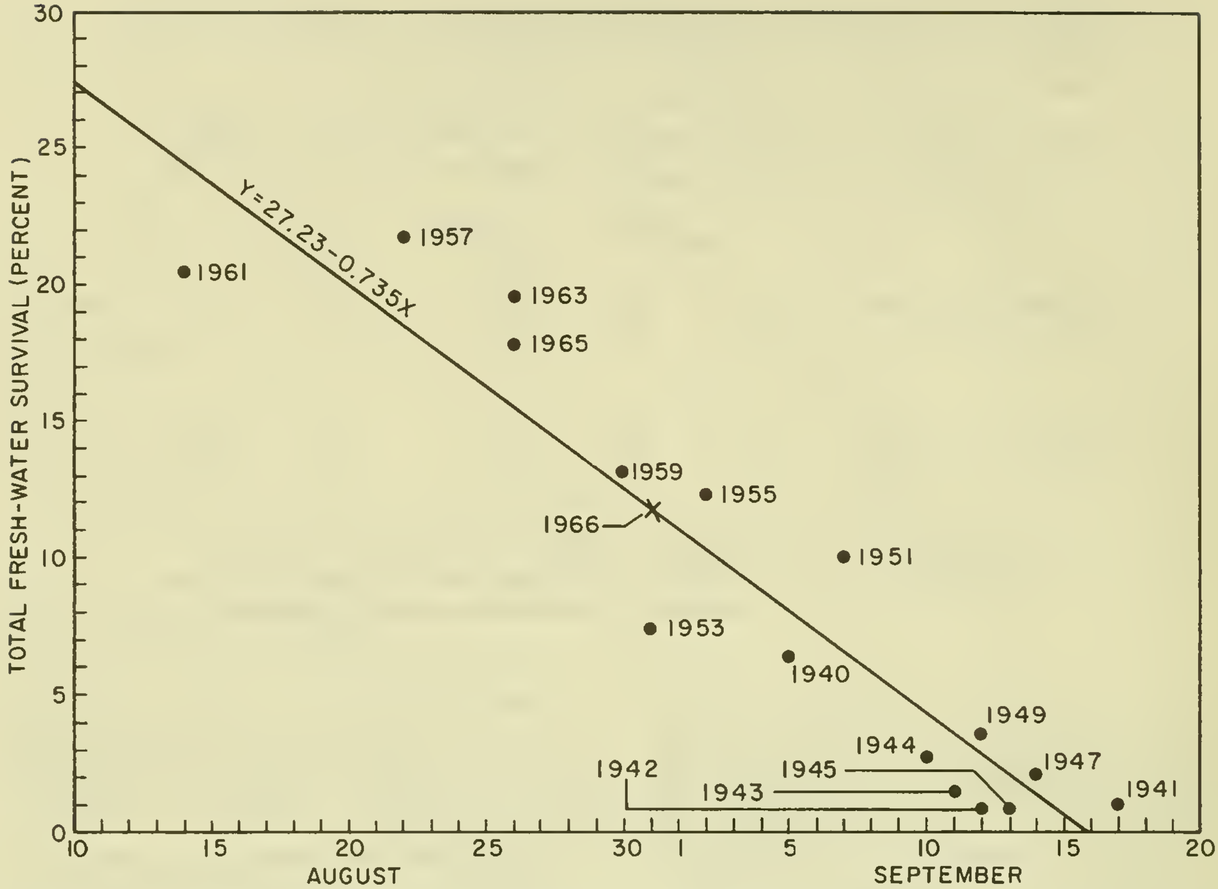

Figure 4.--Relation of fresh-water survival of pink salmon in Sashin Creek to date by which 50 percent of spawners entered the stream for natural escapements of 1,000 or more, in 17 years from 1940 to 1965 (modified from McNeil, 1968). The curve Y = 27.23 - 0.735X is fitted by least squares; X = 0 corresponds to August 10. The 1966 brood year of the transplanted stock is shown for comparison.

Some adult pink salmon have entered Sashin Creek every year since observations began, even though four attempts were made to destroy the run in efforts to measure the amount of recruitment or straying from other streams. The apparent maximum number of strays entered Sashin Creek in 1956 when 933 adults returned from the parent spawning (1954) of six females and two males, from which 661 fry were counted into the ocean in 1955.[3]

The fresh-water survival of progeny of even-year strays (or a mixture of native fish, i.e., those that originated in Sashin Creek as fry and strays) has always been less than that of the adjacent years of the odd-year line, and usually markedly so. The inability of the even-year line to recover was probably due to a combination of inappropriate genetic characters (because of a proportionally large input of strays) and to the fact that too few eggs and fry resulted from the few adults to escape from severe density-independent mortalities in fresh water and the ocean. Because the 287 fish of unknown origin (see footnote 1) entered Sashin Creek in 1964 late (August 30 to September 19), the fresh-water survival of their progeny would be expected to be considerably less than that of the transplanted stock.

Most (87 percent) of the pink salmon that spawned in Sashin Creek in 1964 were the transplanted stock, and the adults that returned in 1966 resembled the transplanted stock more than the native stock in three ways. The fish transplanted in 1964 had remained in the ocean until they were nearly ready to spawn and so did the fish of the 1966 escapement to Sashin Creek; most of the transplanted fish spawned soon after they entered the stream, in early September, as did fish of the 1966 escapement;

[3]Harry, George Y., Jr., and Jerrold M. Olson. 1963. Straying of pink salmon to Sashin Creek, Little Port Walter Bay. Manuscript on file Bur. Commer. Fish. Biol. Lab., Auke Bay, Alaska 99821, 9 pp.

and the transplanted fish were notably large and vigorous, as were those of the 1966 escapement.

FUTURE OF THE TRANSPLANTED STOCK

Because it seems unlikely that the transplanted stock was as well adapted genetically to Sashin Creek as a stock native to the stream, I expect that a selection of those individuals best adapted to their new stream is in progress. If this is true, the good survival of the first two cycles may improve further.

The success of the new even-year line demonstrates that the abundant odd-year line is not now (if it ever was) effective in limiting the success of fish of the even-year line. Conversely, the odd-year line was not affected adversely by the new even-year line but has continued at its high level of abundance and even increased--from about 17,000 in 1963 to 38,000 in 1967.

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